Constraints Analysis in the Applicability of Johkasou System to Cirebon City, Indonesia: Case Investigation for Appropriate Domestic Wastewater Treatment System for Developing Countries

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Abstract

Control over water pollution in developing countries is a laborious challenge due to constraints related to rapid urbanization with weak governance and social awareness besides the technological aspect in finding out and applying the most appropriate options. In the frame of analysis on the most appropriate method for domestic wastewater treatment applicable for developing countries under rapid urbanization, this paper presents analysis of applicability of Japan's on-site *Johkasou* system to the developing countries. The focus was put on constraint analysis during the application of the system in the study area. The experience from the project of technology transfer of *Johkasou* management to the water supply enterprise (PDAM) in Cirebon City, Indonesia was used as the case study. Constraints as regards technical and economic aspects were elaborated during operation and maintenance of the system referred to the data and report provided by Japan International Corporation of Welfare Service (JICWELS). Support of well-established management for operation and maintenance of the system are highly required in applying *Johkasou* system such as those available in Japan; however they are not yet currently the case in Cirebon City. In addition, availability of support for continuous operation requiring a continuous energy-consumption has been an important issue in the Cirebon case. An intermittent operation of aeration system and discharge pump—aiming to save operational cost for electricity—has been attempted to apply. However, the stoppage of aeration system as well as its absence due to equipment breakdown and repair in some periods after starting of operation—has affected the quality of treated effluent especially during high load periods. Additionally, after-effect of aeration stop on the effluent quality was still observed even in the restart period. As regards the required construction cost of the system, the amount is still considered high for low-mid income class family in the study area considering the willingness to pay in the study area. Upon this, considering the cost of the system and the large discrepancy of GDP level, the application of such a hard-measure system is still intricate to be considered for application in the study area. However, further analysis as regards economic analysis including comparison with other methods should be elaborated to find out the most appropriate method for the study area. The application of other methods which are more feasible such as the integration of improved private initiative onsite treatment system and modified public sewerage or community-based decentralized treatment systems with low-cost operation and maintenance should be considered. Furthermore, it is important that future scheme of support from local government to the available well-managed wastewater management systems—by means of any type of appreciation including public statement and a tax waiver/reduction—be established as the model to stimulate a proper management of the treatment system.

Keywords: *Domestic wastewater management; Johkasou system; Constraint analysis; Developing countries;*

1. Introduction

Control over water pollution in developing countries is a laborious challenge due to constraints related to rapid urbanization with weak governance, and social awareness as well as technological aspect concerning the most appropriate options. In the global sanitation perspective, service by sewerage system, taken by about 600 million people [OECD, 2002] has been considered unaffordable for developing countries [Matsui *et al.*, 2003]. Besides, wastewater treatment plantsWWTPs represent one of the major investments due to high capital cost in addition to operation and maintenance cost [Massoud *et al*., 2009]. On the other hand, decentralized treatment systems have been applied as alternatives to treat wastewater.

Johkasou system has been introduced to treat wastewater from buildings as part to respond regions without sewage systems in Japan. This system could be applied in other countries other than Japan with appropriate modification (JICWELS, OECC, 2005). However, investigation is needed using the case study to elaborate further on the implementation of the system in the typical area similar to the study

area. The objective of this study is to investigate the applicability of *Johkasou* system applied in Cirebon City, Indonesia with the example of a medium-scale *Johkasou* system installed at office of PDAM Cirebon, Indonesia.

2. Description of installed *Johkasou* system in Cirebon City

In collaboration with the Indonesian Ministry of Public Works (Cipta Karya), Japan International Corporation of Welfare Services (JICWELS) promoted the survey project on night-soil treatment technology-transfer and has transferred the technology for designing, operating and maintaining of a *gappei-shori* (combined) *Johkasou* to PDAM (Water Supply Enterprise), Cirebon City, Indonesia

Johkasou system has been installed in Cirebon City aimed at reducing BOD to 20 mg/L or less. The treatment processes include a separation-contact aeration system with pre-screening tank, contact aeration, and disinfection. The system of *Johkasou* system applied in Cirebon City can be seen from the Fig. 1.

The configuration of the treatment as well as the figures can be seen in the Fig. 2. Design of facilities is based on influent flow rate of 4.5 m^3/d and BOD concentration of 130 mg/L. The system serves wastewater generated from a group of both new and old government office buildings, housing about 100 employees, with about 50 visitors per day. Capacity and retention time of each unit are also shown in the Fig. 2.

3. Method

The experience from the project of technology transfer of *Johkasou* management to PDAM Cirebon City, was used as the case study. Constraints as regards technical and economic aspects were elaborated during operation and maintenance of the system referred to the data and report provided by Japan International Corporation of Welfare Service (JICWELS).

Based on the analyzed constraints, the applicability of the system in the study area was assessed; some recommended schemes to deal those constraints were addressed. In addition, a consideration for other alternatives that might be applicable particularly those with a low-cost operation and maintenance was proposed.

The *Johkasou* system demonstrates a reliable treatment system. However, it should be encouraged by adequate supporting systems such as well-established institution for operation and maintenance as well as regulation system which are available in Japan.

4. Assessment on technological aspect

4.1 Performance of the system installed

The following is the description of the system performance installed. About five months was needed before the system started to function satisfactorily. Unsatisfied result of BOD effluent that occurred in certain period of monitoring/water quality analysis (>20 mg/L) was reported. An intermittent operation in aeration system (aeration stopped temporarily intended to save energy was considered the cause of such result.

Based on the report [JICWELS, 2000], high influent concentration, e.g. in the case of BOD, and in combination with stoppage of aeration (due to intermittent blower operation intended to save electricity) could probably be considered as factors influencing the lower quality found in the effluent of the *Johkasou* system in several occasion of water quality measurement. This was indicated by an increase in BOD concentration of treated effluent in the 105th day after start-up of the system, which reached 89 mg/L as shown in Fig. (d).

Fig. 1 *Left:* Office Building of Cirebon Water Supply Enterprise (PDAM Kota Cirebon);
Right: Installed *gappei Johkasou* system

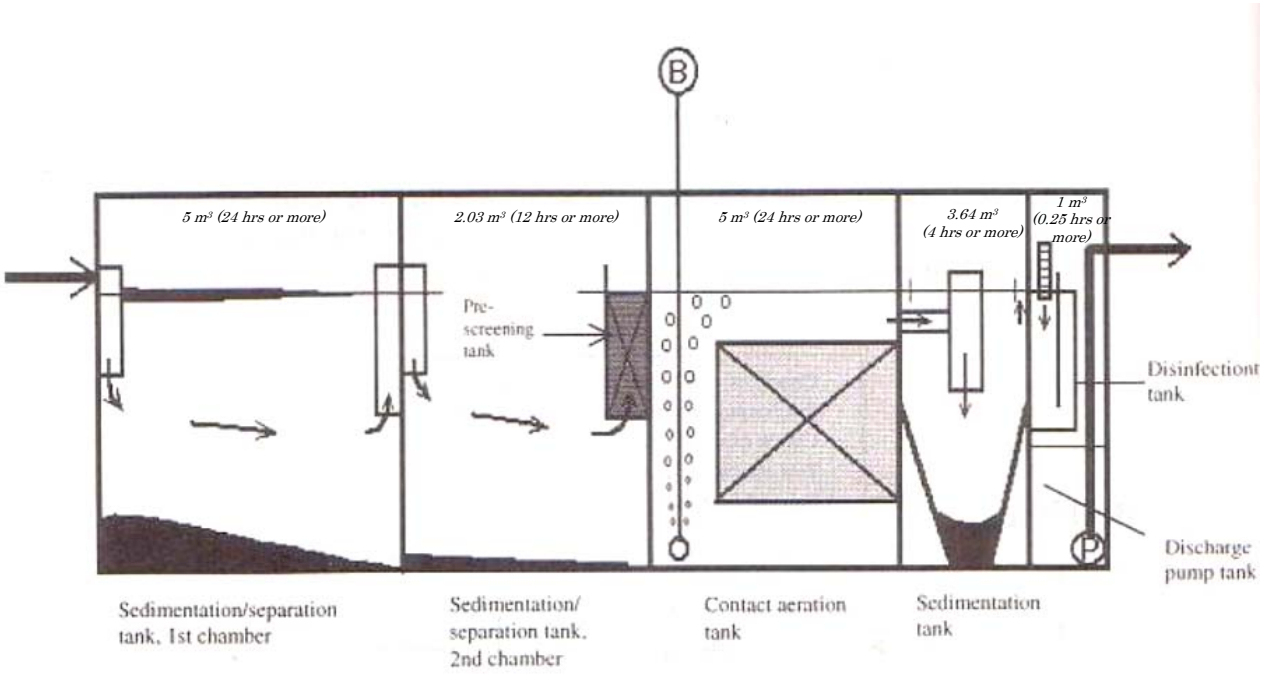

Fig.2 *Johkasou* system applied in Cirebon City [*source*: JICWELS, 2000]

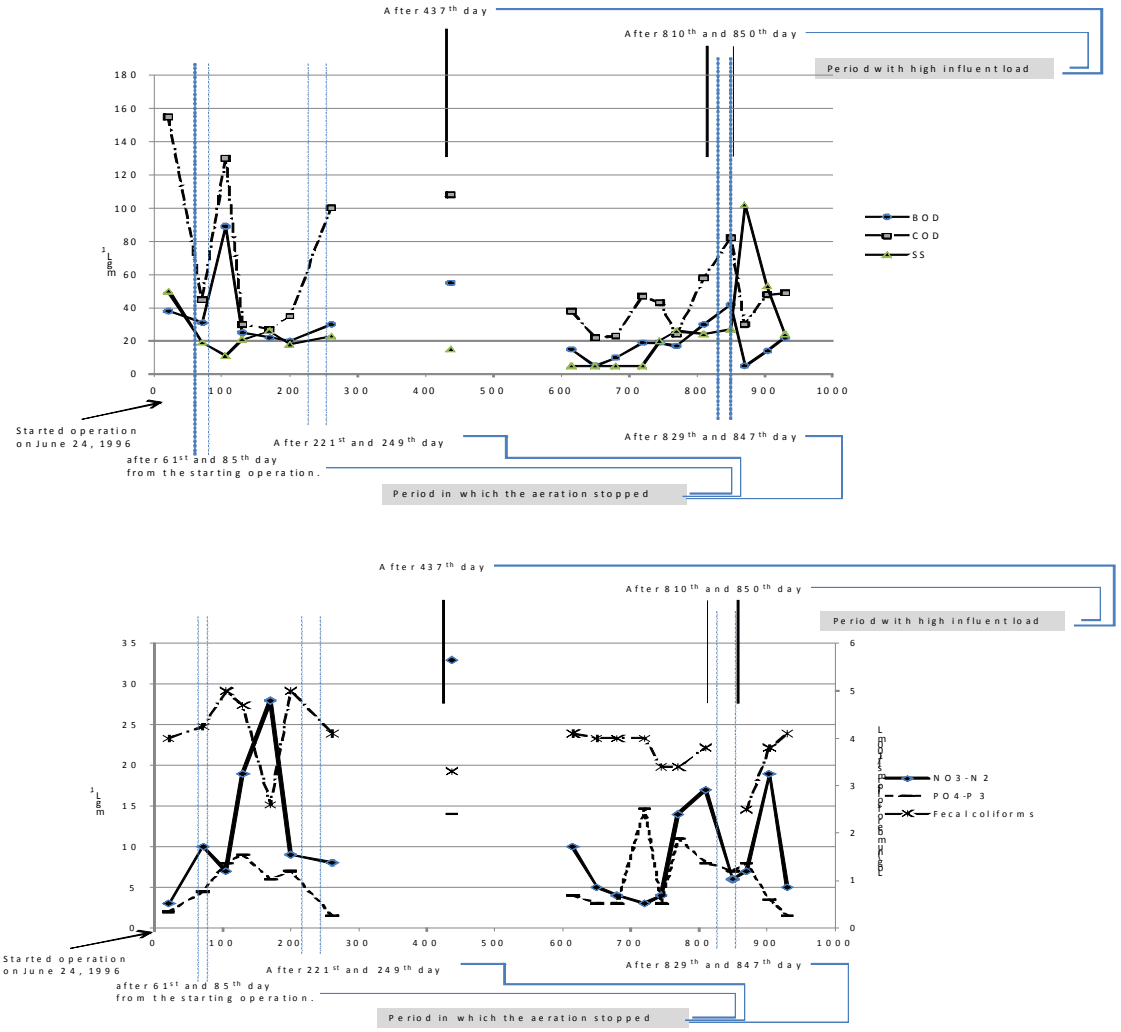

Fig. 3 Results of performance of *Johkasou* system applied in Cirebon City during the period of 1995-2000 (referred to original source: JICWELS [2000] with some estimates)

4.2 Assessment on socio-economic aspects

To introduce *Johkasou* system in developing countries, the greatest effort must be addressed to the cost issues: the use of expensive materials and devices, should be avoided (related to construction stage); a low-cost operation and maintenance methods must be found; sludge should be used as a recycled material whenever possible instead of a large investment in sludge treatment and disposal that completes the functions of a *Johkasou* should be avoided [JICWELS, 2000].

Furthermore, local materials and equipment should be used for construction as much as possible. Imported materials may be allowed if they are not available locally, but future replacement by local products will always be considered. Maintenance, water quality inspection, desludging and transport of sludge can be replaced by locally available materials and methods.

Maximizing the benefit of generally low labor-costs available in developing countries would be considered as a potential factor, which would affect e.g. lower construction-costs of reinforced concrete *Johkasou* compared to that of prefabricated type. Additionally, manual methods for maintenance are preferred to the advanced mechanized ones. However, upgrading the capacities and skills of those workers is required (at least up to minimum skills) e.g. by means of training, which would include those for both proper construction and operation and maintenance.

Table 1 Activities for education on wastewater treatment technology-*Johkasou* system (*source*: JICWELS [2000])

Date	Activities
8-19 April 1996	Organized training (by JICWELS) on technology of *Johkasou* in Japan; two participants from the PDAM
7-8 August 1996	Organized seminar: the *Johkasou* system – technology and operation/maintenance
21 March 1997	Organized seminar: entitled 'Increasing the public and industrial participation on environmental quality through wastewater management
2 December 1997	Organized seminar: entitled 'Environmental regulation by local government for business agency in Cirebon
29 November – 12 December 1998	Organized training (by JICWELS) in Japan: operation and maintenance of *Johkasou; t*wo participants from the PDAM
1998-1999	Received researchers: from Research Institute of Human Settlement (RIHS)-Bandung, Indonesia
1998-1999	Received visitors: from other PDAMs (Water supply enterprise) in Indonesia
1998-1999	Received and performed a presentation: to students from universities in Indonesia

Supported by JICWELS, the Cirebon Water Supply Enterprise (PDAM) has held activities for education and extension of *Johkasou* system. In addition, such activities were also aimed to introduced the functions and performance of Johkasou system to the persons who have interests of alternative technology for wastewater treatment including other participants from other PDAM staffs from other cities/regions and university students (Table 1).

With regard to social aspect, participatory approach is an important issue in accordance with the implementability and sustainability of *Johkasou* system in developing countries. The success or failure of system implementation would depend upon several factors. This would include: whether or not the users voluntarily present the direction of development planning; the system installed was based on users' demand as the most efficient method of achieving the services (demand based) instead of indicating kinds of benefits that the system (*Johkasou*) can provide (supply based). In the introduction of treatment system including *Johkasou*, other key aspects should be taken into account. These include education, work ethic, technicians, and resident awareness.

The grant was given for mechanical equipment (blower) and reagent for WQ analysis due to apparently difficult procurement; it was then stated that procurement of those equipment is locally available including blower as well as chemicals that the granted ones were the same as that they had been using. However, concern appears for future operation and maintenance except such dependency on external resources can be eliminated.

The blower and pumps broke down probably due to overheating (in August 1996, about 40 days after the start of operation) and two motors went out of order in February 1998. However, in both cases technicians of the PDAM were able to repair and restart the equipment [JICWELS, 2000].

A disorder in aeration pipes was reported in the maintenance sheet of June 1998. PDAM's technicians changed the valve and cleared the trouble [JICWELS, 2000]. Such effect on the effluent quality due to the intermittent operation—including periods of equipment breakdown and repair in the 61^{st} to 85^{th} and 221^{st} to 249^{th} days after starting of operation—was reported resulting in such BOD concentration of 20 mg L^{-1}. Additionally, after-effect of aeration stop was still observed even in the restart period leading to such as high BOD effluent concentration especially in the high effluent load.

As regards cost of the system, the total construction cost required was about JPY 350,000 (IDR 35,000,000 including grant from JICWELS for built of the *Johkasou* was IDR 23,992,100 combined with PDAM sharing of 11,000) for serving 160 persons or JPY 2,000/capita. This amount is considered to be still high for low-mid income class

family in the study area. High income family (real estate), commercial areas, offices could probably apply the system.

5. **Discussion on constraints analysis**

From the perspective of sustainability, there have been various constraints in applying the system in the city as typical of area in developing countries. Apart from the matter of construction, these might include the support from the external party with link to the proper attention and obvious responsibility of the institution for taking care—operating and maintaining—the system.

Constraints as it is applied in Indonesia (Cirebon City) include: the construction, operation and maintenance cost, which are higher compared with that of septic tanks or pit latrine; purchasing some equipment e.g. blower or chlorine tablet are difficult and seldom; many people still use septic tank or pit latrine since they believe that it still has a good performance (JICWELS, 2000).

5.1 Cost issue

One of the major cost components in the operation of *Johkasou* system is electricity. Rules regarding use of *Johkasou* commonly applied in Japan require a continuous operation of electrical equipment—the electrical equipment should not be shut-off [JICWELS, 2000]. Such type of operation has been difficult to be applied in developing countries requiring enormous electricity cost—as the case in Cirebon City showed the type of intermittent operation, instead. Such an operation aiming at reducing the level of electricity cost has affected the effluent-quality level especially during high-load periods. It is apparently that for developing countries, such a standard continuous-operation of the system would still be out-of-reach.

5.2 Capacity building and institutional issue

The treatment system of *Johkasou* requires staffs with sufficient technical expertise. Therefore, the availability of highly-skilled operators to properly run the system must be guaranteed. Programs for human capacity building are needed. There is additional requirement on cost for such training programs accordingly. In addition, the required number of operators for such distributed system is higher than that for the centralized system.

5.3 Compliance issue

Increasing demand for compliance has been initially introduced for industrial wastewater in West Java Province but still limited for domestic. In addition, it is important that future design of support from municipal-government for the well-managed wastewater management systems as the models in the region—by means of any appreciation type including public statement up to a tax waiver/reduction—be established.

Support of established elements are required in applying *Johkasou* system such as those available in Japan; however they are not yet currently the case in Cirebon City. Demand for support of well-managed institution responsible for operation and maintenance of the system is high. In addition, availability of support for continuous operation requiring a continuous energy-consumption has been an important issue in the Cirebon case.

A sufficient support from highly-skilled operators and laboratory analysts for performing WQ analysis treatment performance should be guaranteed. For this purpose incorporating with a similar program initiated by the provincial government (WJEPA) for industrial wastewater under EPCM program which has been running since 2005 supported by the Indonesian Ministry of Environment, the Ministry of Industry and Japanese Government (JETRO and JEMAI) could be considered [MoE; WJEPA, 2010].

An intermittent operation of the system was the common type of operation applied. Accordingly, the intermittent operation of aeration system and discharge pump—aiming to save operational cost for electricity or due to equipment breakdown and repair in the 61st to 85th and 221st to 249th days after starting of operation—has affected the quality of treated wastewater resulting in such BOD concentration of 20 mg L^{-1}.

Table 3 Constraints and prospect

Constraint	Prospect
● The availability of strong support of well-management/institution for operation and maintenance of the system ● The difficulty for continuous operation requiring high energy-consumption, chemicals/reagents for water quality analysis; ● Demand for compliance was still considered low especially for domestic sector; the demand for compliance has been initially introduced for industrial wastewater in the Province. ● The need for support from municipal-government for the well-managed systems ● As regards cost of the system, the total construction cost required was about JPY 350,000 for serving 160 persons or JPY 2,000/capita. This amount is considered to be still high for low-mid income class family in the study area considering a low willingness and ability to pay.	● High income family (real estate), commercial areas, offices could probably apply the system. ● Independence of the local in maintaining the equipments e.g. in repair and replacement of broken blower ● It was judged that the water quality analysis laboratory satisfies the necessary conditions and the staff members involved in the analysis work appear to have received the necessary training [JICWELS, 2000] though a limitation was still found. ● Chemicals for the WQ analysis kit made by HACH Company was granted (from Japan); they were given after confirming that they were the same as the chemicals already being used [JICWELS, 2000].

Additionally, after-effect of aeration stop was still observed even in the restart period leading to such as high BOD effluent concentration especially in the high effluent load.

As regards cost of the system, the total construction cost required was about JPY 350,000 for serving 160 persons or JPY 2,000/capita. This amount is considered to be still high for low-mid income class family in the study area considering the willingness to pay in the study area.

Considering the cost construction per capita, the level of WTP of the study area as well as the large discrepancy of GDP level, the application of such a hard-measure system is still intricate to be considered for application in the study area. However, further analysis as regards economic analysis including comparison with other methods should be elaborated.

Furthermore, it is important that future design of support from municipal-government for the well-managed wastewater management systems as the models in the region—by means of any appreciation type including public statement up to a tax waiver/reduction—be established.

6. Conclusion

This paper presents analysis of applicability of Japan's on-site *Johkasou* system to the developing countries. The focus was put on constraint analysis during the application of the system in the study area. Support of well-established management for operation and maintenance of the system are highly required in applying *Johkasou* system such as those available in Japan. However they are not yet currently the case in Cirebon City. Considering the cost of the system and the large discrepancy of GDP level, the application of such a hard-measure system is still intricate to be considered for application in the study area. The application of other methods which are more feasible such as the integration of improved private initiative onsite treatment system and modified public sewerage or community-based decentralized treatment systems with low-cost operation and maintenance should be considered.

References

1. JECES (Japan Education Center of Environmental Sanitation), 2005. *Johkasou* System for Domestic Wastewater Treatment. Tokyo, Japan, 3rd Edition.
2. JICWELS (Japan International Corporation of Welfare Services), OECC (Overseas Environmental Cooperation Centre, Japan), 2005. Manual for installation of *Johkasou* system in developing countries.
3. JICWELS (Japan International Corporation of Welfare Services), 2000. Manual for operation and maintenance of *Johkasou* system at developing countries: Experience from the project of technology transfer of *Johkasou* management to the water supply enterprise (PDAM), Cirebon, Indonesia, JICWELS, Tokyo, Japan.
4. OECD (2002) OECD environmental data compendium 2002
5. Massoud, M.A., Tarhini, A., Nasr, J.A., 2009. Decentralized approaches to wastewater treatment and management: Applicability in developing countries, *J. Environmental Management 90, 652-659.*
6. Matsui, S., Harada, H., Mateo, D., Utsumi, H., Matsuda, T., Shimizu, Y., 2003. Meeting the MDGs on Global Sanitation - a paradigm shift of pathogen and nutrient control, Sustainable future for better living environment for commemorating the opening of a new Korean Academy of Science and Technology (KAST) Building, Korea.
7. Paraskevas, P.A., Giokas, D.L., Lekkas, T.D., 2002. Wastewater management in coastal urban areas: the case of Greece. *J. Water Science and Technology* 35(9), 121-133.
8. MoE (Ministry of Environment), Indonesia < http://www.menlh.go.id/ (in Indonesian); Last accessed in February 2010>
9. WJEPA (West Java Environmental Protection Agency), Indonesia < http://www.bplhdjabar.go.id/ (in Indonesian); Last accessed in February 2010>